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Preliminary Report on the Jaw Tracking System with Six Degrees of Freedom (MM-JI-E, Jaw tracking system)

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Summary

The purpose of this study was to quantitatively analyze the mandibular movement by the Jaw tracking system with six degree of freedom (MM-JI-E). Displacements of the condyles under maximum clenching with successive loss of mandibular supporting zones were measured. The patient, a 29-year-old man, had been treated at an orthodontic clinic between 1994 and 1997, and temporary full coverage crowns were fabricated on four molars of the lower jaw. He showed no signs of abnormality of stomatognathic function. We measured the jaw movements with MM-JI-E, removing the crowns from the distal end of molars to the mesial. The condylar displacement values were displayed and calculated by the measurement of mandibular movement. When the supporting zones were reduced successively, both condyles moved upwards and slightly forwards (87-117°). The maximal condylar displacement values was 700 μm without any support in the molars. We compared the measurements of MM-JI-E with those obtained with another jaw movement tracking system (Bio Pack), with three degree of freedom. The maximum opening paths in sagittal border movement were compared for the two measurement systems. The Bio Pack showed the deflection of the path of anterior maximum opening due to electronic error.

Introduction

Medical engineering has progressed so much that various systems for jaw movement measurement have been reported by many researchers[1~7]. Among them, the measuring system reported by Ueda and Bandou et al. was developed for treatment for temporomandibular disorders. We use usually Gothic arch tracing seeking for centric relation or use Mandibular kinesio-graph (MKG) for jaw movement observation. However, Gothic arch tracing is only two-dimensional (two degrees of freedom) and MKG is three dimensional (three degrees of freedom). The electronic machine

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MM-JI-E used in this study has six degrees of freedom, and can be used to observe all jaw movements from any point (Figure 1). In this study, we quantitatively analyzed of jaw movement traces using mandibular movement analysis with six degrees of freedom. Preliminary measurement was focused on the displacements of the condyles under maximum clenching with successive loss of supporting zones . Another set of measurements was obtained, for comparison, with another jaw movement analyzing system, the Bio Pack system, which has three degrees of freedom.

Materials and Methods

Preliminary measurements were obtained in the displacements of the condyles under maximum clenching with successive loss of supporting zones. The patient, a 29-year-old man, had lost upper left first molar in about 1985, and had been treated at an orthodontic clinic between 1994 and 1997. Extractions because of treatment needs were carried out on the upper right second premolar and the lower right and left second premolar. He showed no disorders in his stomatognathic system. All of his lower molars were restored with full coverage crowns, which were removed for this research. After all full coverage crowns were removed, we rebuilt the supporting zone with temporary crowns. Several weeks later, the interocclusal relationship was confirmed to be stabilized, a lower paraocclusal splint for jaw movement measurement was made by casting, and an upper paraocclusal splint was made using a ready- made splint fixed with self curing resin (Figure 2). Figure 3 shows the external view of the jaw tacking apparatus with six degrees of freedom. This system is composed of the six software components as follows: JMB: for setting up the reference points; JMI: for jaw tracking measurement; JMT and JMA2: for jaw tracking analysis; PSET: for setting up the optional point; and FREAD: for reading out the analyzed results. The jaw tracking device has sensors on each of its four sides (Figure 4). At the beginning of measurement, one must set up the reference points in the maxilla, using the JMB; these are composed of the incisal point and both first molar central fossae in the maxilla. We measured jaw movement with the JMA2 after initial setting, while removing the temporary crowns from distal end of the molars to the mesial. Measurements of condylar movements were calculated from the hard copy from the JMT after indicating the condylar positions with PSET, while the supporting zones were successively reduced. The Bio-Pack jaw tracking device with three degrees of freedom was compared with the MM-JI-E. We compared only the tracking orbits of the anterior maximum opening path in sagittal border movement in this patient.

Results and Discussion

When the supporting zones were reduced, both condyles moved upwards and forwards. The value of condylar displacement was 700 μm, while the supporting zones were lost completely by removing the occlusal contacts of the temporary crowns of 36, 37, 46, and 47 under maximum clenching (Figure 5). The mandible was displaced upwards 40 μm even with the complete occlusal contacts of the supporting zones. It was further displaced upwards 9 μm when all of the supporting zone contacts were reduced. These values of the incisal point displacements accorded well with the area in normal subjects reported by Harada et al.[8]. Both condyles moved upwards and forwards (87 -117°) when the Frankfurt horizontal plane was at zero degrees in the sagittal plane (Figure 6). These results are similar to those reported by Igarashi *et al.*[9] and Kühl *et al.*[10] (Figure 7). When we compared about the movements of the anterior maximum opening paths in sagittal border movement of the Bio-Pack and MM-JI-E, the Bio-Pack showed a point of deflection in the anterior

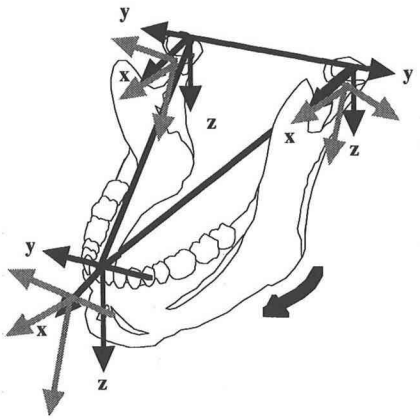

Figure 1: Six degrees of freedom on the jaw movement

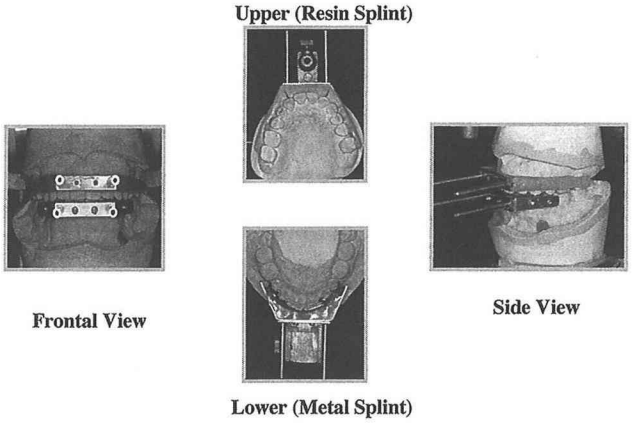

Figure 2: External view of splint used in this study

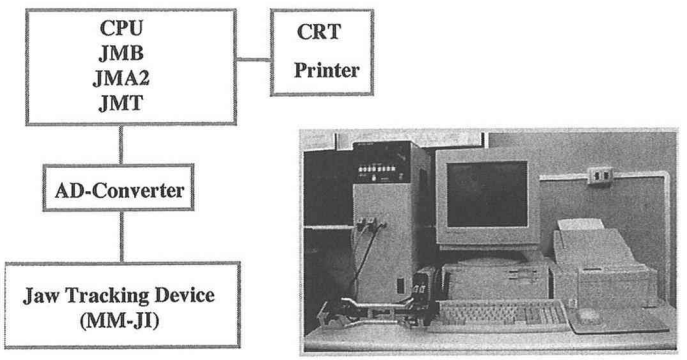

Figure 3: Block diagram and external view of jaw movement analyzer

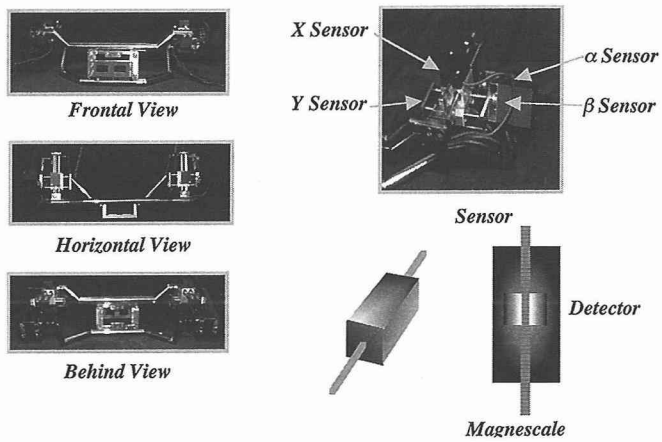

Figure 4: External view of jaw tracking device and scheme of sencer

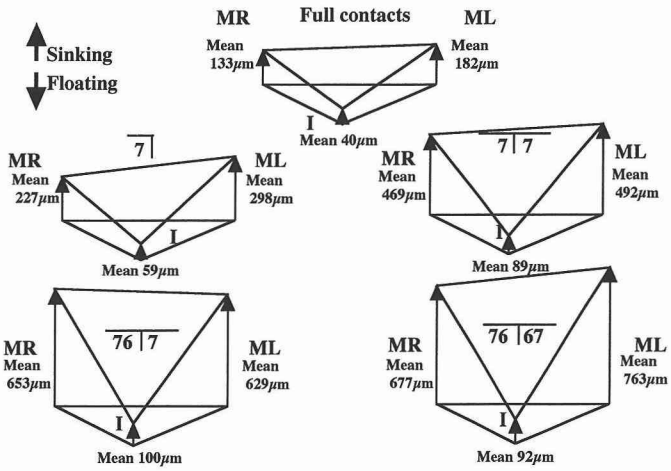

Figure 5: Displacements of the condyles according to successive loss of supporting zone

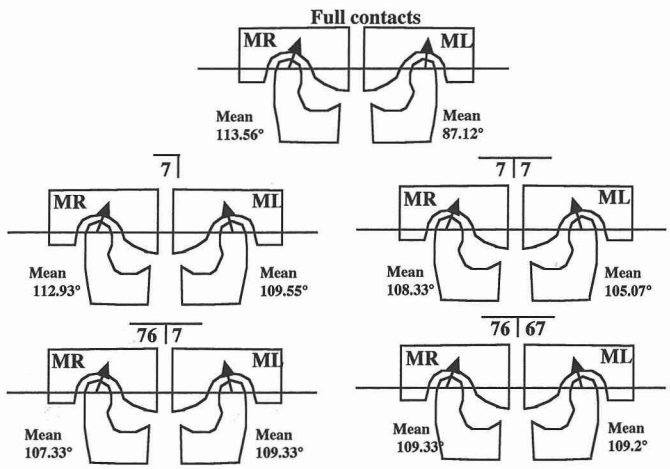

Figure 6: Angle of the condyles according to successive loss of supporting zone

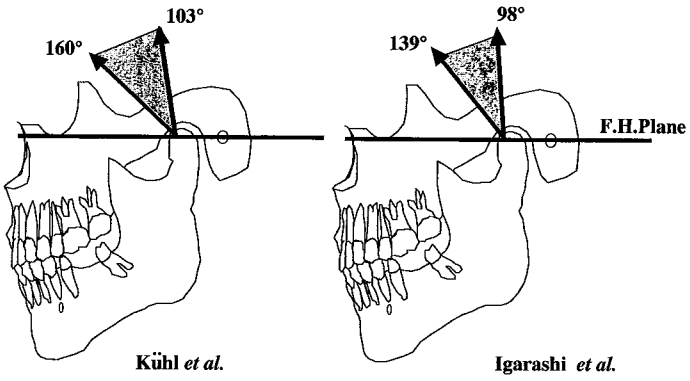

Figure 7: Displacement of the condyle under maximum clenching and lost of supporting zone (Kühl et al.[10] and Igarashi et al.[9])

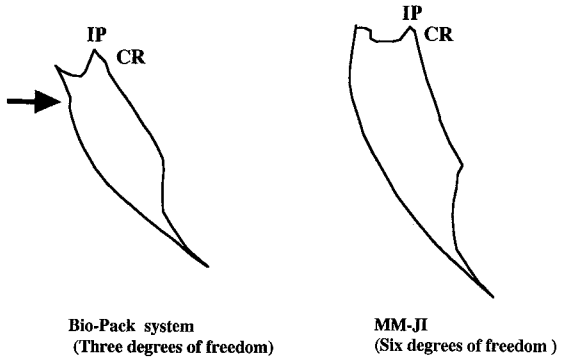

Figure 8: MM-JI and Bio-Pack tracking orbits in sagittal border movement of the patient.

maximum opening path, which was thought to be artificial compared to the same movement observed with the MM-JI-E (Figure 8). MM-JI-E was very accurate in measuring the jaw movement.

Conclusion

The purpose of this preliminary study was to quantitatively analyze the jaw movement using the MM-JI-E, a jaw tracking system with six degrees of freedom.

Following results were obtained;

1. Displacements of the condyles during successive loss of supporting zones under maximum clenching were measured. The condyles moved upwards and forwards, while the supporting zones were reduced. The condylar displacement value was up to 700 μm and the both condyles moved upwards and forwards (87-117°).
2. The Bio-Pack jaw movement analyzing system was compared to this system.
   It showed a partly deflective tracking curve for the anterior maximum opening path.

These results indicate that the MM-JI-E is very accurate and useful for measuring human jaw movement.

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抄録：6自由度顎運動測定装置の試用

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本研究では下顎運動を把握するための第一歩として6自由度下顎運動測定装置（MM-JI-E）の試用を行った．試用としては咬合支持を失ったときの顆頭変位量を求めた．被検者は1994—1997年に歯列矯正行を行い，全部鋳造冠が下顎両側第1・2大臼歯部に装着されている29歳の男性である．なお，顎口腔系，顎関節に特記するような疾患を有していない．この被検者にて暫間補綴物を最後方臼歯より除去し，MM-JI-Eを用いて下顎の変位を測定した．顆頭の変位量については下顎運動から計算し，求めた．今回の実験で最大に咬合支持を失ったとき顆頭は700 μm変位した，また，最大クレンチングを行った場合，両側顆頭は前上方に変位した（フランクフルト平面を基準とした場合87—117°）．また，Bio Packシステム（3自由度顎運動測定装置）とMM-JI-Eの比較を切歯点における矢状面最前方運動路について運動軌跡の比較検討を行った．その結果，Bio Packシステムでは矢状面最前方運動路に変曲点が現れた．これらの結果からMM-JI-Eは顎運動を非常に正確に計測できることが示唆された．